Good morning everyone, I am Edgar Martinez, Program Manager for the Microsystems Technology Office. Today, it is my pleasure to dedicate the next few minutes talking to you about transformations in future military systems through innovations in semiconductor materials and devices.

More specifically, I would like to talk about Gallium Nitride and related wide bandgap compound semiconductors.

But before we start talking about the properties of these materials and its impact in future military systems, lets spend a few minutes talking about another DARPA success story.

During the last two decades, DARPA has been instrumental in developing compound semiconductor technologies, including GaAs and InP for analog, digital, and optical applications. Projects such as, MIMIC, MAFET, and the GaAs Insertion Programs, which were focused in the development of microwave, millimeter wave, digital, and mixed signal components have enabled many of today's military radar, communications, and electronic surveillance sensors.

All these projects have provided the department of defense with an industrial base for affordable military components while motivating new opportunities in today's commercial markets.

However, this technology transitioned from the military industry to today's commercial markets materialized just recently after the communication industry realized the benefits of what several decades ago was considered to be a military unique technology.

Last year alone, the semiconductor industry reported an unprecedented 11 billion dollars in sales of compound semiconductors. This figure corresponds to a 36% increase in sales from the previous year.

This is attributed to the rapid expansion of the wireless communication market worldwide.

The bottom line is, what yesterday was considered to be a unique military challenge, it became today' commercial reality.

Although significant progress in compound semiconductor materials and device technologies was made during the MIMIC and MAFET eras, globalization, emerging threats, and new military system concepts are driving component requirements to the point of which commercial technology fails to meet current military needs.

For example, many future military systems will require analog components with power densities higher than those achievable with today's GaAs mmic technology.

In addition, requirements for more bandwidth, higher linearity, higher efficiency, and lower-noise performance will transform active sensors to see further with improved clarity. In order to meet this increasing demand in component performance, we must consider all options with respect to materials and devices.

Silicon (Si), despite its advantages of large substrates and high integration densities, lacks the performance for very high frequency and high power analog applications.

GaAs- and InP-based compound semiconductors, which possess somewhat different material properties than Si, are more suitable for analog, very high speed, and mixed signal applications.

But because their bandgap properties limit component power and efficiency, these materials usually require very large-area devices that could often result in low yield, and high cost components.

On the other hand, GaN and wide bandgap semiconductors have at least 2.5 times larger bandgap and at least three times higher electron saturation velocity than GaAs, allowing devices to sustain two orders of magnitude higher voltage levels than any other compound semiconductor device.

These properties make these materials ideal for very high power, low noise, high dynamic range analog and mixed signal applications.

However, Mother Nature is not always kind to technology.

As to date, the demonstration of GaN components is limited by poor materials and poorly controlled fabrication processes.

Today's substrate technology is considered to be one of the biggest impediments in the demonstration of electronic devices.

Unlike traditional semiconductor materials such as, Si, GaAs, and InP, GaN does not possess a native substrate that perfectly matches its lattice constant.

So far the "brute force" approach is to use alternate substrates resulting in devices with far below theoretical performance.

Recent breakthroughs in crystal growth technology indicates the potential to develop larger area GaN substrates that could help overcome the limitations imposed by heteroepitaxial growth techniques in highly mismatched material systems.

In addition to these substrate issues, unprecedented high temperature processes are required for the growth of high-quality materials, creating a new set of challenges unique to this technology.

Overcoming these challenges is critical in controlling the material quality and the reproducibility of electronic and optical devices.

Only after overcoming these technical limitations in material growth and processes, we must be able to realize the full potential of GaN and related compound semiconductors, enabling the demonstration of a new class of electrical and optical devices with superior performance compared to its current Si and GaAs counterparts.

Comparing the state of practice of solid-state power amplifiers, we must realize that we have reached the fundamental performance limits of GaAs technology. Under these limits, we have provided solid-state solutions to many military systems such as radar arrays, satellite communications, and smart weapon seekers.

Above these limits, power combining techniques and vacuum electronics are commonly used to provide the required output power.

However, such systems are usually inefficient, bulky, costly, and less reliable. Successful development of GaN technology could extend by hundred times the performance range of current solid- state amplifiers and well into the regime currently addressed by vacuum electronics.

The development of this technology is considered to be high risk, but likewise with a higher payoff.

This is why DARPA is focusing in comprehensive initiatives for the development of GaN and related wide bandgap semiconductor technologies for photonic and analog applications.

Our initiatives require well-defined and focused efforts in the areas of materials and devices.

The material technology thrust is helping us to advance the state of practice of bulk crystals enabling the fabrication of low cost, large area, high quality substrates suitable for the growth of GaN and related wide bandgap semiconductors. In addition to substrate technology, we are focusing in demonstrating innovative epitaxial processes and techniques for improving material quality and device performance.

This thrust includes processes that will result in highly uniform and reproducible epitaxial layers with low background impurities but proper doping concentrations.

In the device technology area, our interest extends to the optimization of structures for devices with unique performance.

These devices will enable innovative component demonstrations for various selected applications.

Our last focus area addresses the heterogeneous integration of GaN devices with other electronic materials and devices to form microsystems with unique capabilities.

Our strategy ... is to manage ... risk!!!!

We must learn the trade-off between materials, devices, and enclosure properties for optimum component performance.

In order to accomplish our mission, we must require multi-disciplinary teams capable to address these challenges while translating information at all levels of the "technology food-chain", creating a good balance between technology push and application pull. We are currently leveraging experience from previous developments --- minimizing technological re-invention while speeding up progress.

We are also leveraging knowledge, materials, expertise, and resources from the emerging commercial sector that is currently focusing in developing these materials for less demanding optical applications.

The end result is the sharing of commercial resources to achieve the economy of scale required for affordable military components.

Successful demonstration of analog GaN integrated components with higher power densities, higher efficiencies, and lower noise figures, will create new opportunities in multifunctional RF systems, radar, electronic surveillance, high-speed communications, electronic warfare, and smart weapon systems.

A recent break-through at the University of California at Santa Barbara has demonstrated the ability of these materials to achieve ten times higher power densities over the best GaAs device as to date.

This proof that indeed GaN and wide bandgap semiconductor devices can operate at higher voltages, and higher power densities enabling smaller and more efficient components which eventually will result in the reduction of system size, cooling requirements, and ultimately system cost.

In addition, improvements in output power will result in longer sensor range and broader operational bandwidth, enabling multi-functional apertures.

Anticipated improvements in component linearity and noise performance will enable the sensor ability to track slow moving targets in heavy clutter or in the presence of enemy jamming.

Though the properties of GaN and related wide bandgap semiconductor materials are suitable for analog electronics, the bandgap properties of these materials make them ideal and desirable for many optical applications as well.

With proper bandgap engineering, these materials could emit and sense wavelengths in the visible and ultra-violet regions of the electro-magnetic spectrum.

Today, DARPA is pursuing the optimization of aluminum gallium nitride materials for the demonstration of ultra-violet photo-diodes.

These devices will enable a new class of photo-detectors capable to operate in the solar-blind region of the electro-magnetic spectrum.

Our challenges include the ability to grow high aluminum mole fraction materials with bandgaps suitable for detecting wavelengths between 280 and to 260 nm.

In addition to the demonstration of these materials, the ability to achieve consistent device uniformity over large areas allows the demonstration of focal plane array integrated circuits.

Eventually, the integration of these focal plane arrays with proper readout electronics will lead us to the demonstration of compact and low cost imaging systems capable of detecting airborne missiles at moderate range.

Today's UV solar blind detection capabilities are implemented with photo-multiplier technology, which is considered to be bulky, fragile, and too expensive for many military platforms. Successful demonstration of AlGaN detectors could lead to six hundred time improvements in system performance, volume, and cost. These detectors could be also integrated with multi-spectral infrared imagers for all weather, missile early threat warning capabilities.

In addition to these military unique applications, other potential opportunities for this technology can be envisioned in bio-defense, engine monitoring, flame and combustion control.

It is also anticipated that the commercial demand for GaN and related wide bandgap semi- conductor materials, devices, and components will increase exponentially during this decade. with a market forecast exceeding $5 billion dollars in sales by the year 2010.

Many of these commercial opportunities will be created as a result of advances in materials and devices for the less demanding optical applications including traffic control, large area full color displays, automotive, medical, illumination, and consumer electronics such as mass data storage and wireless communications.

Though our interest is not in pursuing these commercial opportunities, the leverage that we can get from these applications will provide the department of defense with the economies of scale required for affordable military systems.

But lets keep in mind that the commercial material requirements are not going to match our military needs.

So let's remember that in the past DARPA has been instrumental in developing compound semiconductor technologies that have enabled affordable military sensor and communication systems.

Although twenty years ago GaAs was considered to be a military unique challenge, today it has become a commercial reality.

As we stand here today, we can see history almost repeating itself. GaN and related wide bandgap materials are emerging as obvious candidates to address many of the current military unique requirements that are impossible to meet with today's commercial technologies.

In order to harness the potential benefits of this technology, we must overcome the fundamental material and device challenges that are currently limiting technical progress. It is important that we focus our attention on comprehensive development efforts ... to ensure advances in technology and to effectively transition ideas from the research laboratory to fielded systems in the shortest time possible.

Finally, the transformation of future military systems will be expected as YOU help DARPA creates technology innovations with GaN materials, devices, and components.

Thanks for your attention and enjoy the rest of DARPATech.